SCIENCE

FRIDAY, JUNE 10, 1910

CONTENTS

MSS. intended for publication and books, etc., intended for review should be sent to the Editor of SCIENCE, Garrison-on-Hudson, N. Y.

PRACTICAL SCIENCE[1]

MEN who spend their lives in universities are apt to develop certain unfortunate peculiarities. These peculiarities may not make them less happy, or less useful to their professional students, but they diminish the appreciation of the community at large. In the life of an instructor or investigator of university rank there is a peculiar kind of isolation that is bound to react.

It is partly the isolation of a subject, which is more or less segregated from general human interests, at least in the aspects of it the university man is cultivating. As a consequence, he feels that his world is quite apart from that one in which the majority of men are living. He is conscious of an interest distinct from their interests, which seem therefore relatively trivial. This sense of intellectual aloofness does not result in a feeling of loneliness, but rather in a feeling of superiority, unconscious in many cases, but often naïvely expressed.

It is also the isolation of authority, which comes from mastery of a subject and from association with students who recognize this mastery. To speak with authority in intellectual matters, to give the deciding word, to meet a constant succession of inferiors, is apt to affect any man's brain. Either he becomes dogmatic in expression, or he must hold himself in check with an effort. It is the same reaction that was observed in the case of the clergy, when acknowledged authority in position

[1] Address at the winter convocation, 1910, of the University of Chicago.

resulted in an assumption of authority in belief.

The larger the university, the more intense does this sense of the isolation of superiority and of authority become, for it is stimulated by association with its own kind. There is much honest effort to break down this barrier between the scholars who represent universities and the great host of men who represent the community. These men are not so isolated, but they are just as dogmatic in their own way, and they are immensely influential. Even when the two groups mingle, the scholar is often only a man of incidental interest, who possesses much curious information about many useless things. And the scholar usually enjoys being drawn out and made to display his curiosities, for it has the familiar flavor of the classroom, with its intellectually inferior students.

Of course such contact between scholar and community is not the effective one, for it is merely that of audience and entertainer. Here are two groups of men, both powerfully equipped, who should be mutually stimulating in all that makes for progress. Mutual stimulation can follow only after mutual understanding. It is not for me to explain the community to the scholar, but rather to explain the scholar to the community. Even this subject is far too large, for scholarship has many phases, all the way from artistic appreciation to scientific synthesis. I shall try to explain in outline only the scientific aspect of scholarship, and its significance to the community.

It is evident that the public is somewhat interested in scientific research. The most available index of the present interest is furnished probably by the newspapers and magazines, which try either to respond to the desires of their readers, or to cultivate desires. Even a cursory examination of the material they furnish, which may be said to deal with research, shows that it is scanty in amount, sensational in form and usually wide of the mark. The fact that it is scanty in amount is a cause for congratulation, if it must involve the two other features. The sensational form is a concession to what is conceived to be public taste; and while to a scientific man this form seems to exhibit the worst possible taste, the serious objection is that to secure the form truth is usually sacrificed. Some of the results of this kind of information are as follows:

Men engaged in research are looked upon in general as inoffensive but curious and useless members of the social order. If an investigator touches now and then upon something that the public regards as useful, he is singled out as a glaring exception. If an investigation lends itself to announcement in an exceedingly sensational form, as if it were uncovering deep mysteries, the investigator becomes a "wizard," and his lightest utterance is treated as an oracle. The result is that if the intelligent reading public were asked to recite the distinguished names in science, they would name perhaps one or two real investigators unfortunate enough to be in the public eye, several "wizards," and still more charlatans. The great body of real investigators would be known only to their colleagues, thankful that they were not included in any public hall of fame. And yet the public is not to be blamed, for it is giving its best information; and the fact that it has even such information indicates an interest that would be wiser were it better directed. This better direction is dammed up behind a wall of professional pride, which makes an investigator look askance at any colleague who has broken through it. The intelligent public is certainly interested, but it is just as certainly

not intelligently interested. I wish to analyze the situation briefly.

There is a conventional application of the term science, which I will use for convenience. Thus applied, there has arisen a classification of science into two phases, called pure science and applied science. This distinction is one that not only exists in the public mind, but it is also reinforced by published statements from colleges and universities. An attempt to define these two kinds of science reveals the fact that the distinction is a general impression rather than a clear statement. A general impression is usually sufficient for the public, but it ought not to be sufficient for the universities.

If the impression be analyzed, it seems that pure science is of no material service to mankind; and that applied science has to do with the mechanism of our civilization. The distinction, therefore, is based upon material output. In other words, pure science only knows things, while applied science knows how to do things. This impression, rather than distinction, has been unfortunate in several ways.

The public, as represented by the modern American community, believes in doing things; and therefore to them pure science seems useless, and its devotees appear as ornamental rather than as vital members of human society, to be admired rather than used. The reaction of this sentiment upon opportunities for the cultivation of pure science is obvious.

On the other hand, the universities, as represented by their investigators, believe in knowing things; and therefore to them applied science seems to be a waste of investigative energy, and its devotees appear to be unscientific, very useful, but not to be acknowledged as belonging to the scientific cult.

The reaction of this sentiment sometimes has been to avoid the investigation of problems that have an obvious practical application, and to justify Lowell's definition of a university as "a place where nothing useful is taught."

In this atmosphere of mutual misunderstanding the public and the universities have continued to exist and to make progress, all the time acknowledging their interdependence by mutual service.

In recent years, however, a new spirit is taking possession of the public and it has invaded the universities. In fact, so conspicuous have the universities become in the movement that they seem to be the leaders; certainly they furnish the trained leaders. The new spirit that is beginning to dominate increasingly is the spirit of mutual service. It is called by a variety of names, dependent upon the group that proclaims it; it is narrow or broad in its application, dependent upon the moral and intellectual equipment of its promoters; but it is the same enduring idea.

The university is no longer conceived of as a scholastic cloister, a refuge for the intellectually impractical; but as an organization whose mission is to serve society in the largest possible way. Furthermore, this service is conceived of not merely as the indirect contribution of trained minds, a contribution of inestimable value, as we believe; but also as the direct contribution of assistance in solving the problems that confront community life.

This new animating spirit is so attractive and inspiring, appealing to what seem to be our best impulses, that it threatens to become a real danger not only to universities, but to the whole scheme of education down to the primary school. The reaction is natural, and therefore inevitable; but its demands must be recognized as representing the primary and extreme recoil stage of a new motive. The new motive must not

eliminate all the old motives, but must adjust itself efficiently among them. For example, there is abroad an increasingly insistent demand that in the primary and secondary schools all instruction in pure science shall be discarded and various forms of applied science substituted, the imaginary distinction being that which has been indicated. The same pressure is being felt in the college, not to the extent of substitution, but to the extent of adding impossible courses and weakening existing ones. My present thesis, however, is interested chiefly in the fact that the same pressure has begun to be applied to the research work at universities. This pressure is applied not only by public demand, which voices the supporting constituency of most universities, especially of the middle west; but also by the extensive scientific work of state and federal governments, in which for the most part the immediate practical aspect must dominate. The more recent developments at our state universities are impressive illustrations of this pressure; and as a result, in such universities scientific research, in connection with problems that do not seem to be related at present to the welfare of the community, is living in a depressing atmosphere.

It is time for the public and for the managers of universities to understand the real relation that exists between what they have been pleased to call pure science and applied science. I can not hope to make a statement that will appeal to all concerned, but it may serve some useful purpose.

As an introductory illustration, there may be outlined the usual steps that science has taken in the material service of mankind. An investigator, stimulated only by what has been called "the delirious but divine desire to know," is attracted by a problem. No thought of its usefulness in a material way is in his mind; he wishes simply to make a contribution to knowledge. No one can appreciate the labor, the patience, the intellectual equipment involved in such work unless he has undertaken it himself. The investigator succeeds in solving his problem, and is satisfied. Later, perhaps many years later, some other scientific man discovers that the results of the former may be used to revolutionize some process of manufacture, some method of transportation or communication, some empirical formula of agriculture, some practise in medicine or surgery. The application is made and the world applauds; but the applause is chiefly for the second man, the practical man. Any analysis of the situation, however, shows that to the practical result both men contributed, and in that sense both men, the first no less than the second, were of immense material service. The ratio that exists between scientific men of the first type and those of the second is not known, but there is very great disparity.

Another illustration is needed as a corollary. In this case an investigator, stimulated by the desire to serve the community, is attracted by a problem. He also wishes to make a contribution to knowledge. He succeeds in solving his problem, perhaps makes his own application, and is satisfied. Later, some other scientific man discovers that the results of the former may be used to revolutionize certain fundamental conceptions of science. His statement is made and the scientific world applauds; and this time also the applause is chiefly for the second man, the pure scientist. The analysis of this case shows, however, that to the scientific result both men contributed; and that both men were of large scientific service.

A third illustration is needed to complete the real historical picture of progress

in scientific knowledge and in its material applications. A practical man, not trained as an investigator, faces the problem of obtaining some new and useful result. His only method is to apply empirically certain formulæ that have been developed by science, but with ingenuity and patience he succeeds, although he is not able to analyze his results. And yet, his procedure reveals to a trained investigator a method or certain data that lead to a scientific synthesis of the first order.

With such illustrations taken to represent the actual historical situation, what may be some of the conclusions?

It is evident that responsibility for the material results of science is to be shared by those engaged in pure science, those engaged in applied science and those not trained in science at all. The only distinction is not in the result, therefore, but in the intent. As one of my colleagues has aptly said, the difference between pure science and applied science, in their practical aspects, resolves itself into the difference between murder and manslaughter; it lies in the intention. So long as the world gets the results of science, it is not likely to trouble itself about the intention. In every end result of science that reaches the public, there is an inextricable tangle of contributions. Between the source of energy and the point of application, there may be much machinery, and perhaps none of it can be eliminated from the final estimate of values. And yet, the public is in danger of gazing at the practical electric light and forgetting the impractical power house; and schools are being asked to turn on the electric light and to shut off the power house.

Another conclusion is that all application must have something to apply, and that application alone would presently result in sterility. There must be perennial contributions to knowledge, with or without immediately useful intent, that application may possess a wide and fertile field for cultivation. It is just here that the menace to education is evident. When education in science becomes a series of prescriptions, to be followed without understanding and without perspective, it will train apprentices rather than intelligent thinkers. Of course there is a place for just this kind of training and there are individuals who need it; but the place does not seem to be the schools for general education, and the individuals are evidently not all those who pass through these schools, or even a majority of them.

A third conclusion is that there is nothing inherent in useful problems that would compel their avoidance by an investigator who wishes to contribute to knowledge. While such an investigator should never be handicapped by the utilitarian motive, at the same time he should never be perversely non-utilitarian. I feel free to make this statement, for perhaps no field, within the confines of my own general subject, seems to be more non-utilitarian than the special one I have chosen to cultivate. There is no reason why a university, especially one dominated by research, should not include among its investigations some that are of immediate concern to the public welfare.

A final conclusion may be that all science is one; that pure science is often immensely practical; that applied science is often very pure science; and that between the two there is no dividing line. They are like the end members of a long and intergrading series; very distinct in their isolated and extreme expression, but completely connected. If distinction must be expressed in terms where no sharp distinction exists, what seems to me to be a happy suggestion, made by one of my colleagues,

is the distinction expressed by the terms fundamental and superficial. They are terms of comparison and admit of every intergrade. In general, a university devoted to research should be interested in the fundamental things of science, the larger truths, that increase the general perspective of knowledge and may underlie the possibilities of material progress in many directions. On the other hand, the immediate material needs of the community are to be met by the superficial things of science, the external touch of more fundamental things. The series may move in either direction, but its end members must always hold the same relative positions. The first stimulus may be our need, and a superficial science meets it, but in so doing it may put us on the trail that leads to the fundamentals of science. On the other hand, the fundamentals may be gripped first, and only later find some superficial expression. The series is often attacked first in some intermediate region, and probably most of the research in pure science may be so placed; that is, it is relatively fundamental; but it is also relatively superficial. The real progress of science is always from the superficial toward the fundamental; and the more fundamental are our results, the more extensive may be their superficial expression. In short, my subject, "practical science," is no subject at all, if it implies a special kind of science, for all science is practical.

I can not leave science in the position of working on the chance that some of its results some day may be found to be of material service to mankind. I have been speaking the language of those who measure usefulness in terms of its market price, and even at that low level the results of science easily control the market. Perhaps there are some who think that this is the only level at which the usefulness of science is conspicuous; for it is often thought of as the Pullman car of our civilization, and not the passenger; something that contributes to our convenience and comfort, but something quite apart from our intellectual and moral selves.

To my mind, the largest usefulness of science, its contribution of immeasurable value to human welfare, is on the intellectual level. It has developed and is continuing to develop the scientific attitude of mind, an attitude that has literally revolutionized thinking, so that all subjects and all education have become scientific. No more impressive testimony to this wide and revolutionary influence of the scientific spirit could be given than that contained in the numerous memorial volumes of last year in honor of Charles Darwin, for his contribution was not so much the theory of natural selection as the scientific point of view. Perhaps the volume from his own university illustrates this most compactly. It contains papers written by 29 men, easily among the leaders in their respective fields, and representing the widest possible range of universities, and all united in saying that this embodiment of the scientific spirit revolutionized not only zoology and botany and geology and astronomy, but also the study of language, of history, of sociology, of philosophy and of religion. This means that all subjects worthy of study and worthily studied have become scientific. It also means that this same scientific attitude is available for our social problems, immensely more important and vital than our material problems, for they deal with human welfare. Without attempting to analyze in any adequate way what has been called the scientific attitude of mind, or the scientific spirit, I wish to indicate three of its useful characteristics.

1. *It is a spirit of enquiry.*—In our ex-

perience, we encounter a vast body of established belief in reference to all important subjects, such as society, government, education, religion, etc. It is well if our encounter be only objective, for it is generally true, and a more dangerous fact, that we find *ourselves* cherishing a large body of belief, often called hereditary, but of course the result of early association. Nothing seems more evident than that all this established belief that we encounter belongs to two categories: the priceless result of generations of experience, and heirloom rubbish. Toward this whole body of belief the scientific attitude of mind is one of unprejudiced inquiry. So far as the attitude is prejudiced, it is unscientific. This is not the spirit of iconoclasm, but an examination of the foundations of belief. It is evident that this spirit is diametrically opposed to intolerance, and that it can find no common ground with those who affirm confidently that the present organization of society is as good as it can be; that our republic represents the highest possible expression of man in reference to government; that the past has discovered all that is best in education; that the mission of religion is to conserve the past rather than to grow into the future. This is not the spirit of unrest, of discomfort, but the evidence of a mind whose every avenue is open to the approach of truth from every direction. For fear of being misunderstood, I hasten to say that this beneficial result of scientific training does not come to all those who cultivate it, any more than is the Christ-like character developed in all those who profess Christianity. I regret to say that even some who bear great names in science have been as dogmatic as the most rampant theologian. But the dogmatic scientist and theologian are not to be taken as examples of "the peaceable fruits of righteousness," for the general ameliorating influence of religion and of science are none the less apparent. It is not the speech of the conspicuous few that is leavening the lump of human thought, but the quiet work of thousands of teachers.

2. *It is a spirit which demands that a claimed cause shall be demonstrated.*—It is in the laboratory that one first really appreciates how many factors must be taken into the count in considering any result, and what an element of uncertainty an unknown factor introduces. Even when the factors of some simple result are well in hand, and we can combine them with reasonable certainty that the result will appear, we may be entirely wrong in our conclusion as to what in the combination has produced the result. For example, the forms of certain plants were changed at will, by supplying to their surrounding medium various substances. It was easy to obtain definite results, and it was natural to conclude that the chemical structure of these particular substances produced the result, and our prescription was narrowed to certain substances. Later it was discovered that the results are not due to the chemical nature of the substances, but to a physical condition developed by their presence, a condition which may be developed by other substances or by no substances; and so our prescription was much enlarged.

There is a broad application here. In education, we are in danger of slavery to subjects. Having observed that certain ones may be used to produce certain results, we prescribe them as essential to the process, without taking into account the possibility that other subjects may produce similar results. In religion, we are in danger of formulating some specific line of conduct as essential to the result, and of condemning those who do not ad-

here to it. That there may be many lines of approach to a given result, if that result be a general condition, is a hard lesson for mankind to learn.

If it is so difficult to get at the real factors of a simple result in the laboratory, and still more difficult to interpret the significance of factors when found, in what condition must we be in reference to the immensely more complex problems that confront us in social organization, government, education and religion, especially when it is added that the vast majority of those who have offered answers to these problems have had no conception of the difficulties involved in reaching truth? The proper effect of such knowledge is not despair, but an attentive and receptive mind.

The prevailing belief among the untrained is that any result may be explained by some single factor operating as a cause. They seem to have no conception of the fact that the cause of every result is made up of a combination of interacting factors, often in numbers and combinations that are absolutely bewildering to contemplate. An enthusiast discovers some one thing which he regards and perhaps all right-thinking people regard as an evil in society or in government, and straightway this explains for him the whole of our present unhappy condition. This particular tare must be rooted up, and rooted up immediately, without any thought as to the possible destruction of the plants we must cultivate.

This habit of considering only one factor, when perhaps many are involved, indicates a very primitive and untrained condition of mind. It is fortunate when the leaders of public sentiment have gotten hold of one real factor. They may overdo it, and work damage by insisting upon some special form of action on account of it, but so far as it goes it is the truth. It is more apt to be the case, however, that the factor claimed holds no relation whatsoever to the result. This is where political demagoguery gets in its most unrighteous work, and is the soil in which the noxious weeds of destructive socialism, charlatanism and religious cant flourish.

3. *It keeps one close to the facts.*—There seems to be abroad a notion that one may start with a single well-attested fact, and by some logical machinery construct an elaborate system and reach an authentic conclusion, much as the world has imagined that Cuvier could do if a single bone were furnished him. The result is bad, even though the fact may have an unclouded title. But it happens too often that great superstructures have been reared upon a fact which is claimed rather than demonstrated. Facts are like stepping stones; so long as one can get a reasonably close series of them he can make some progress in a given direction, but when he steps beyond them he flounders. As one travels away from a fact its significance in any conclusion becomes more and more attenuated, until presently the vanishing point is reached, like the rays of light from a candle. A fact is really influential only in its own immediate vicinity; but the whole structure of many a system lies in the region beyond the vanishing point.

Such "vain imaginings" are delightfully seductive to many people, whose life and conduct are even shaped by them. I have been amazed at the large development of this phase of emotional insanity, commonly masquerading under the name of "subtle thinking." Perhaps the name is expressive enough, if it means thinking without any material for thought. And is not this one great danger of our educational schemes, when special stress is laid upon

training? There is danger of setting to work a mental machine without giving it suitable material upon which it may operate, and it reacts upon itself, resulting in a sort of mental chaos. An active mind, turned in upon itself, without any valuable objective material, certainly can never reach any very reliable results. It is the trained scientific spirit which recognizes that it is dangerous to stray away very far from the facts, and that the farther one strays away the more dangerous it becomes, and almost inevitably leads to self-deception.

It is such an attitude of mind that scientific training is contributing to the service of mankind. This does not mean that all scientific men exhibit this attitude to the full, but that it is their ideal. This ideal has realized some tremendous results during the last half century, and there is every evidence that it is accumulating momentum for a much larger expression. Compared with this contribution, the material usefulness of science seems tawdry. In general, the world's standards of usefulness are tawdry, but education ought to correct them rather than maintain them.

The conclusion is that all science is immeasurably useful, from fundamental to superficial, on the material plane and on the intellectual plane; and that in these two regions of human need it is the most valuable practical asset the world possesses.

JOHN M. COULTER

BOTANY IN ITS RELATIONS TO AGRICULTURAL ADVANCEMENT[1]

FEW things are more interesting to one of a philosophic cast of mind, especially if he be something of a botanist or agriculturist, than a growing collection of plant varieties. However sluggish of intellect one may be, such a collection—representing forms developed in the long history of the cultivator's art—is sure to excite one's interest regarding their origin. At first thought it would seem that as practically all of the numerous varieties that exist in cultivated plants have been developed as it were under the eye of the grower, we should have a pretty clear understanding and agreement as to their mode of origin. Yet few subjects have proved more perplexing. The stock answer of the breeder or gardener to one's inquiries is usually embodied in the words *sports* and *hybrids*. Is this answer adequate? The enormous importance of the subject, it would seem, should have incited the most intensive study into the problem. Few plants in their ordinary wild forms will repay cultivation. It is only through their improvement that a permanent agriculture became possible. The very baffling nature of the problems presented, instead of attracting students, seems to have repelled them. Systematic botanists have looked upon cultivated plant varieties as artificial products—useful, no doubt, but utterly subversive to notions of classification obtained from plants in their natural habitats. Therefore, they have been neglected and no plants are so rare in museum collections as our common cultivated ones. Such a thing as a reasonably complete herbarium of cultivated plant varieties nowhere exists. The natural result of this has been that the systematic botany of cultivated plants is in woeful confusion. As a rule, numerous botanical species have been based on purely agricultural varieties, but in some cases the opposite extreme is found and perfectly distinct species are confused as garden varieties. As a natural consequence of this neglect by botanists, the great mass of information we have concerning any cultivated plant is largely

[1] Address of the retiring president before the Botanical Society of Washington, March 5, 1910.